

Value Enhancement through Refractories
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High Value added Refractories for high Quality Steelmaking

E. Jankovits, V.P. Africa, Near/Middle East & CIS & India, RHI AG, Austria, erwin.jankovits@rhi-ag.com, +43 50213-6131
S. Chetlapalli, Director Sales Steel, RHI India, shyam.chetlapalli@rhi-ag.com, +91 33 4018 1201
J. Cappel, M.D., Cappel Stahl Consulting GmbH, Germany, juergen.cappel@cappel-consult.com, +49 2132-960052

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Abstract

Production of iron and steel historically started already in the ancient times based mainly on military and only some civil applications. Today steel products are widely used in all kinds of modern industries like construction, transport logistics, automotive, household goods, white goods, etc. With expanding application also the requirements on product properties and safety of the steel based products were increased. Today highly performing products require defined properties in narrow tolerances, which lead to sophisticated process control solutions. Not only the steel composition must be adjusted, but cleanliness of the steel products from non-metallic impurities comes more into the focus of the steel consumers.

The refractory Industry always has supported its customers with high demanding technology solutions. The introduction of high wear resistant refractory materials for the lining of metallurgical vessels, the development of the submerged purging technology and the introduction of shrouded casting are namely only a few steps which supported the performance improvement of steelmaking technology during the last decades.

Was the steel industry during the last two decades focused on growth, basically happening in the emerging regions of the world, during the upcoming next period of time rather a consolidation to cut off over-capacity must be expected. The latest statistical trends indicate a 3-5% lower production for 2015 compared to 2014 worldwide. Naturally also the refractory industry will be affected by these obvious industrial trends since iron and steelmaking counts for more than 70% of the total refractory world markets.

Industrial consolidation phases in opposite to growth phases are generally characterized by oversupply of the markets which leads to price and margin decline of the affected goods and products. Was the business in the past mainly driven by quality and availability aspects, it can be predicted that value in use solutions provided to the markets are one possible solution to survive in a simple "best price" oriented environment. The knowledge of the interaction between supplied product quality and product performance in customer application becomes the key of success.

1. Introduction

In **Figure 1** below the long history world steel production curve is shown starting from the age of industrialization until today [1]. It becomes obvious that during the first 100 years industrialization happened in the countries of the old world, driven by the fabrication of iron and steel and products of these metals. The first records of the steel industry production in China are dated back to the 1950ies. As shown in Figure 1 until the year 2000 there was only poor development in the country with the biggest population in the world. In the meantime, after WW2 in Europe, North America and Japan a tremendous growth boosted the steel production from 100 mtpy up to over 700 mtpy in 1970. Then in the developed countries the 2 oil price crisis in 1970 and 1985 resulted in an almost 30 years lasting period of stagnation/consolidation, before in 2000, basically caused by the start-up of industrialization in MENA, South America and India a new success story became true.

At the same time the substantial industrial growth in China started, which boosted the steel production of the country from 15% in 2000 to now 50% of the world steel production. In the same time also world steel production has doubled. Today we know that this growth was in majority the growth of the Chinese industry.

In the rest of the world only 14% growth could be realized during the 20 years period between 1985 and 2005 at all.

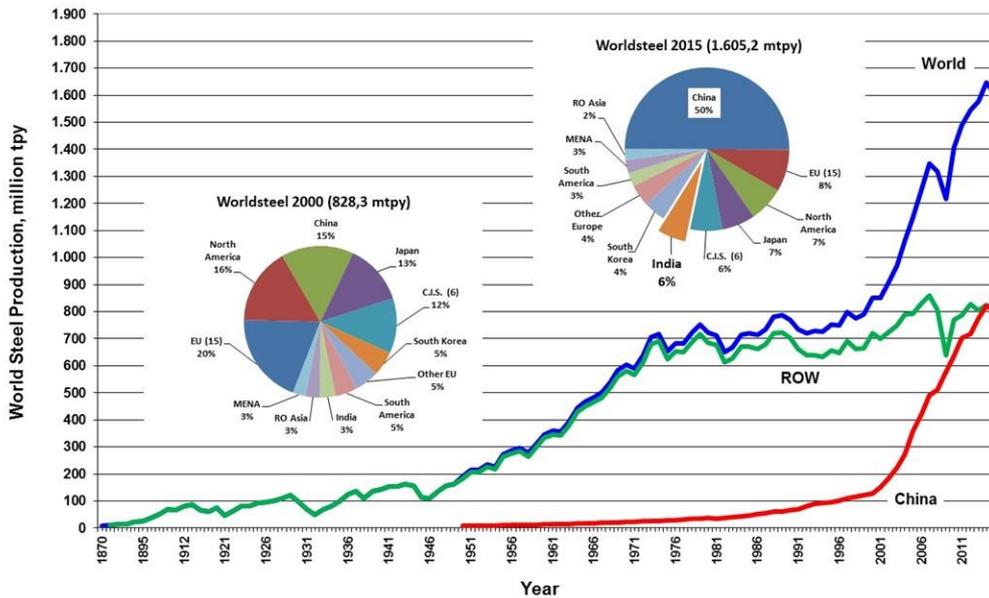


Figure 1: World Steel Production 2015 [1]

The downturn in the years 2008-2011 as can be seen from the figure only was a temporarily distortion and only happened in the developed part of the world. China continued its growth without major disturbance.

We all are aware what kind of troubles this development in China caused for raw material availability, quality and pricing. We all saw dramatic price rallies as well as quick stock devaluations. A remarkable number and named companies have totally changed their supply chain strategy from strictly downstream market oriented to backwards integrate. International trade became more substantial influenced by political interest with export duties on raw materials as well as import duties for semi-finished products. In a global world of today trade barriers are a serious business obstructions.

The actual market situation, represented by the 2015 figures shows a completely different trend as known from the last two decades. All in sudden –but not unexpected- the growth on the domestic market in China stopped and now the access steel producing capacity is flooding the world markets. In consequence also in the developed countries production is slowed down. This new situation is heavily demanding for consolidation activities. One possibility for escape is to invest into higher value added products. And higher value added steel products of course automatically require higher value added refractory products.

2. Steel Quality Classification

Table 1 shows a simplified steel classifications system [2, 3]. Steel types are generally split into Low alloy and alloyed steels, depending on their wear and corrossions resistance. According to the table only stainless steels, which count for a total of 41,7 mtpy (2,5%) of the world steel production are classified as alloyed steels. The low alloyed or not alloyed steels are further split into Carbon ranges from ultra-low (ULC), low (LC), medium (MC) and high (HC) grades.

In each group plain and sophisticated steel grades are shown ad example grades and example applications are listed. Plain steels are generally not alloyed, HSLA, heat treatment and tool steels are low to medium alloyed steel grades. The low to medium alloyed steel grades count in total for roughly 165 mtpy (10%) of the world steel production (incl. the stainless steel production).

So 90% of the world steel production are plain Carbon steels. Nevertheless also in these segments a differentiation in high and low quality applications must be considered. Of course everybody is aware of the different value in use requirements of exposed, plain Carbon automotive sheet or electrical steel compared to plain Carbon rebar construction steel. The share of the very simple steel, without any additional quality requirements today counts for 50% of the total.

Steels							
Steel Type	Low alloy steels					High alloy Steels	
Carbon Range	LC, Low Carbon Steel <0.25 %		Medium Carbon Steel 0.25-0.60 %C	High Carbon Steel 0.60-1.4 %C		Corrosion resistant	
Steel Type Detail	Plain LC steel	HSLA steel	Plain MC steel	Heat treatment steel	Plain HC steel	Tool steel	Stainless steels
Alloying Concept	No additions	Nb, Ti, Cu, V, Ni, Mo	No additions	Cr, Mo, B, Ni	No additions	Cr, V, Mo, W	Cr, Ni, Mo
Typ. Grade	1010	3410	1040	4340	1095	4190	304
Hardenability	0	+	+	++	++	+++	0
Tensile Strength	-	0	+	++	+	++	0
Elongation	+	+	0	-	-	--	++
Typ. Application	Autobody Building Panels	Pressure vessels Structures	Crankshaft Bolt Hammers Blades	Pistons Gears Wear resistant parts	Wear resistant parts	Drills Saws Dies	Chemical and food processing, High temperature applications

— Increasing strength, cost, decreasing ductility —>

Table 1: Steel Type & Grade Classification [2, 3]

When it comes to differentiation and survival in a shrinking market stressed by international trade from overseas, it is very clear, that those producers which are operating at the low product quality end actually are the most vulnerable market participants. No surprise that generally a steel producer trend to escape in higher quality and value market segments is rather preferred than to try to survive with a ultra-low production cost strategy. This is clear taking into account that even the most efficient production cost and productivity results can be sacrificed by currency and export subsidiary political motivated manipulations easily.

Quality related, i.e. value added solutions for the customers cannot easily being replaced by imports. Too complicated is the supply chain in case of asking other, than standard products.



Figure 2: Steel Performance & Properties Model

In **Figure 2** the various steel product properties related to performance in application and performance in processing are shown. The Steel Property triangle demonstrates that a huge number of properties must be influenced by the process know how to control only a few metallurgical variables, namely: chemical composition, steel cleanliness, steel surface appearance and steel microstructure shape.

Surface appearance is determined by cold rolling parameters and surface coating methods applied. Steel microstructure is controlled by the casting, rolling and heat treatment condition of steel processing and is a

knowledge base of downstream steel processing. The chemical composition is determined by the steel type and grade. Steel cleanliness is the major subject of the upstream steel processing. To produce clean and super-clean steel treatment intensity is the key for success. Therefore in modern steel making all kind of treatment facilities are assembled to process routes, as shown in **Figure 3** below [4].

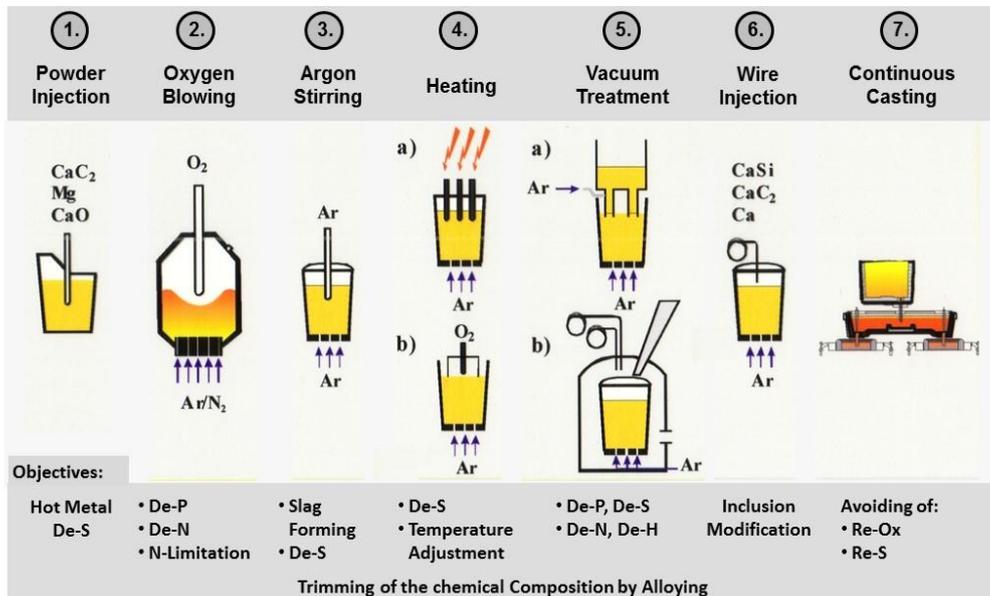


Figure 3: Steel Product Quality Improvement by Treatment Intensity Increase [4]

Hot metal is De-Sulfurized in special HMD-treatment facilities where powder is injected into the melt. In the melting vessel the high Carbon hot metal is refined to low Carbon steel. During the process De-Phosphorization can be controlled to very low levels. Tramp element control is guaranteed by careful selection of cooling agents, like scrap, HBI and iron ore. During tapping alloying agents and slag fluxes are charged into the melt. In the Argon stirring station steel composition and temperature are homogenized and metallurgical slag is formed. In the steel reheating stations the temperature of the melt is adjusted to compensate heat losses during processing and the steel composition is adjusted to narrow specification limits. De-S can be forced. In the vacuum treatment process the elements of Carbon and Sulphur can be removed to ultra-low levels. In steel soluble gases like Hydrogen and Nitrogen can be removed. Oxygen will be removed to very low levels by Carbon-Deoxidation or by cleaning the steel from non-metallic Oxides by coagulation. During wire injection final trimming of the steel composition is adjusted and inclusion modification is applied. During casting avoiding of air contact, avoiding of ladle and tundish slag carry over and separation of non-metallic inclusions from the melt to the tundish and mould slag are the keys for success.

Looking to this long sequence of liquid steel treatment it becomes obvious that the refractory concept applied in the different aggregates and vessels of this process chain must be carefully adapted to the intensity of the metallurgical treatment required to meet the steel property specification. Since most of the steel plants are not producing a monoculture steel type & grade but a wide range of different products, the lining concept must be adapted/compromised for the best performance result related to the steel product mix.

3. Refractory Market & Quality Classification

For this purpose a wide range of refractory materials are available on the international markets. In **Figure 4** the recent market volume was estimated with 40,7 mtpy (equivalent to almost 30 bUSD) in 2014, worldwide. 60% of this market are represented by the demand of the steel industry, the rest is dedicated to non-ferrous, non-metallic and other high temperature process applications. It is not surprising that again China is dominating this market by 55%. This figure correlates very well with the share of the Chinese steel production on the world steel production.

It can be stated from market research studies [5, 6] that the measurable, average, specific refractory consumption worldwide is around **15 kg/t**, with China being at elevated levels of about 20 kg/t, Europe and America (North & South) being at about 10 kg/t and Japan achieving the lowest average consumption figures of about 8 kg/t of steel.

Of course beside these regional effects, also structural differences must be taken into account. It is obvious that electrical steel mills melting scrap have significant lower refractory consumption (best in class: 5-7 kg/t), whereas integrated mills, with more aggregates in the process chain have a 30-40% higher demand (best in class: 8-10 kg/t).

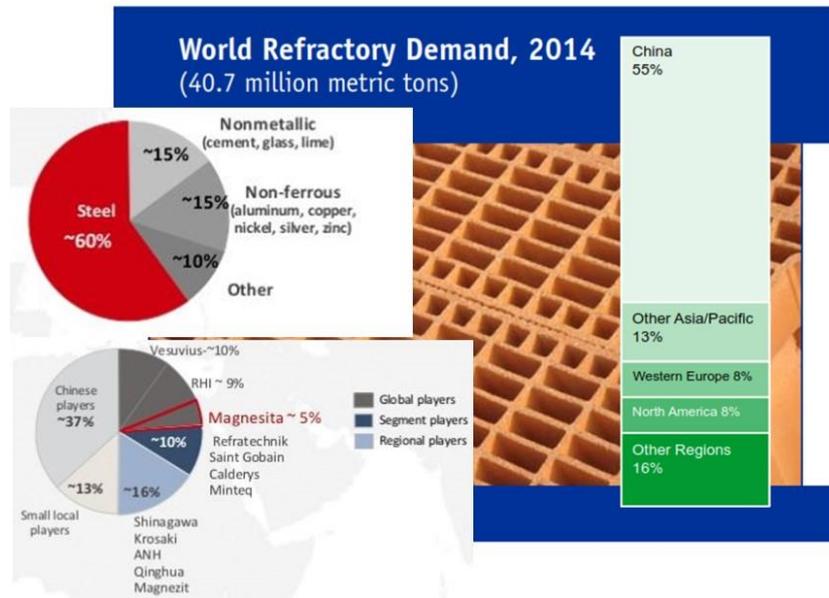
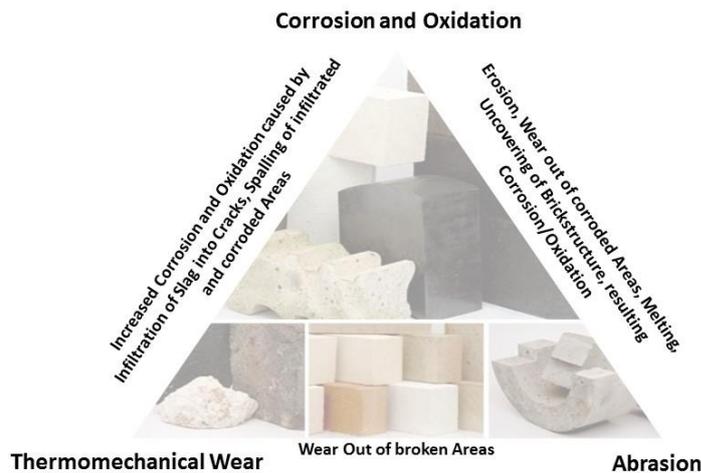


Figure 4: World Refractory Market [5, 6]

Another criteria is the steel type produced. In stainless steel production for example the best producers in class are at a level of 15 kg/t. Since these figures are not uniform in all steel plants worldwide, it becomes obvious that the process “know how” of the steel producers and at the same time the availability of high quality and value refractory products are the key for low consumption figures.

In **Figure 5** the refractory wearing model is shown. The main factors for high performance results are resistance against thermocycling, abrasion and slag corrosion and oxidation. On the one hand high wear and stress resistance are the key success factors for high and cost efficient refractory performance, on the other hand it must be taken into account that refractory wear always is related to formation of non-metallic particles which must be separated from the steel melt into the top slag.



The Refractory Lining of metallurgical Vessels is heavily stressed during melting and refining of the steel. All possible interactions between Steel, Slag and Refractory Material must be taken into account to avoid negative impact on steel Product Quality Results

Figure 5: The Refractory Wearing Model [7, 8]

These particles can be formed during the steel treatment simply by abrasion, as well as by disintegration caused from thermocycling cracking and also from chemical reactions of steel or slag with refractory

components. All these possible interactions must be taken into account when a refractory concept for a steel plant is designed.

A general classification of refractory materials available is given below [9]:

- Group classification according to the main chemical components (e.g. Al₂O₃ or MgO content),
- Type of main raw material (natural, synthetic or composite material, e.g. Co-sinter and not burned, calcined, sintered or melted),
- Type of bond (ceramic by firing at > 800 °C, inorganic-chemical by reaction ≤ 800 °C, hydraulic (setting at room temperature), organic and fused cast),
- Type of subsequent treatment (heat-treatment up to 800 °C, impregnated),
- State upon delivery (shaped, unshaped),
- True porosity (dense < 45 vol-%, heat insulating ≥ 45 vol-%),
- Method of working (for unshaped materials) and
- Intended application/use.

A more detailed overview about type, composition and refractory properties like porosity, refractoriness, thermocycling & abrasion resistance and resistance against acidic or basic slag and flux attack is given in **Table 2**, below.

Refractory	Major Component (% by wt.)	Refractoriness (°C)	Porosity (%)	Thermal Resistance	Abrasion Resistance	Acidic Slag & Fluxes	Basic Slags & Fluxes
Silica	SiO ₂ = 93-96	1.700	16-18	Good (1.600 °C)	Good	Fair	Poor
Low Alumina	SiO ₂ = 40-45 Al ₂ O ₃ = 35-55	1.700	20-23	Good	Good	Good	Medium
High Alumina	SiO ₂ = 50-60 Al ₂ O ₃ = 40-45	1.750	20-29	Good	Good	Good	Poor
Magnesite	MgO = 80-95 Fe ₂ O ₃ = 2-7 Al ₂ O ₃ < 4	< 2.000	20-23	Poor	Medium	Poor	Good
Dolomite	CaO = 58 MgO = 40	1.650	= 20	Poor	Medium	Poor	Good
Carbon	C = 85-90	< 2.000	22-32	Good	Poor	Good	Fair
Chromite	Al ₂ O ₃ = 15-23 Cr ₂ O ₃ = 15-30 Fe ₂ O ₃ = 10-17 MgO = 14-20	1.800 - 1.900	18-25	Fair	Medium	Fair	Good
Carborundum	SiC = 89-91	< 2.000	17-20	Good	Good	Good	Poor
Zirconia	ZrO ₂ = 67	= 2.500	-	Good	Good	Good	Poor

Table 2: Refractory Type & Grade Classification [9]

Since liquid steel making always happens in the temperature ranges above 1.650 °C (tapping temperature of the melting units) and for high quality applications require the use of basic top slags and fluxes, the variety of materials is already limited to Magnesite, Dolomite and Mag-Chrome refractory for the melting units. For the shrouding system of the continuous casting process generally Alumina-Graphite materials are applied worldwide, because they are resistant against reactions of Al-killed steel with refractory material.

4. Refractory Application Examples

Amongst many other application examples the discussion of the ladle lining design is a good reference for the value in use discussion, see **Figure 6**. On the left side of the figure the various functional elements of ladle treatment are shown which indicates the different stress types which must be outperformed by the ladle refractory. We have:

- Temperature load caused by liquid steel and slag.
- Thermocycling stress because of the “full” and “empty” ladle cycle.
- Mechanical load by the weight of steel and slag.
- Abrasion by porous plug or lance stirring and bath movement during vacuum treatment or during arcing.
- Chemical attack by basic slag, FeO and MnO in the slag and Oxygen blowing to the slag/metal.

On the right side of the Figure a “zoned”, balanced lining concept for modern steel teeming ladles is shown. The total refractory weight of a standard 150 t/heat ladle is roughly 40,5 t refractory (REF) (0,27 tREF/tSteel). The Lining is split into horizontal zones from the hot face to the cold face and vertical zones from the bottom to the top. It is completed by the ceramics for ladle purging and steel flow control (slide gate).

Typically today the refractory quality mix is MgO-C bricks at the hot face (wear lining = 69,5%) and high Alumina or burned Magnesia bricks behind (permanent lining = 28,8%). It is recommended to install a insulation brick plus a fiber insulation layer between the steel shell and the permanent lining to reduce the steel shell temperatures. Also between the permanent and the wear lining a sufficient gap to be filled with ladle backfiller material is recommended to compensate the thermal expansion of the wear lining bricks.

Castables in Ladles are basically used to equalize or incline the ladle bottom-for better drain out-. Also the well blocks are locked into the bottom lining by using castables. Mortar is used for the permanent lining only. Finally the expansion joint between the wall lining and the upper lip ring is filled with ramming or gunning mix to lock the lining into the steel shell.

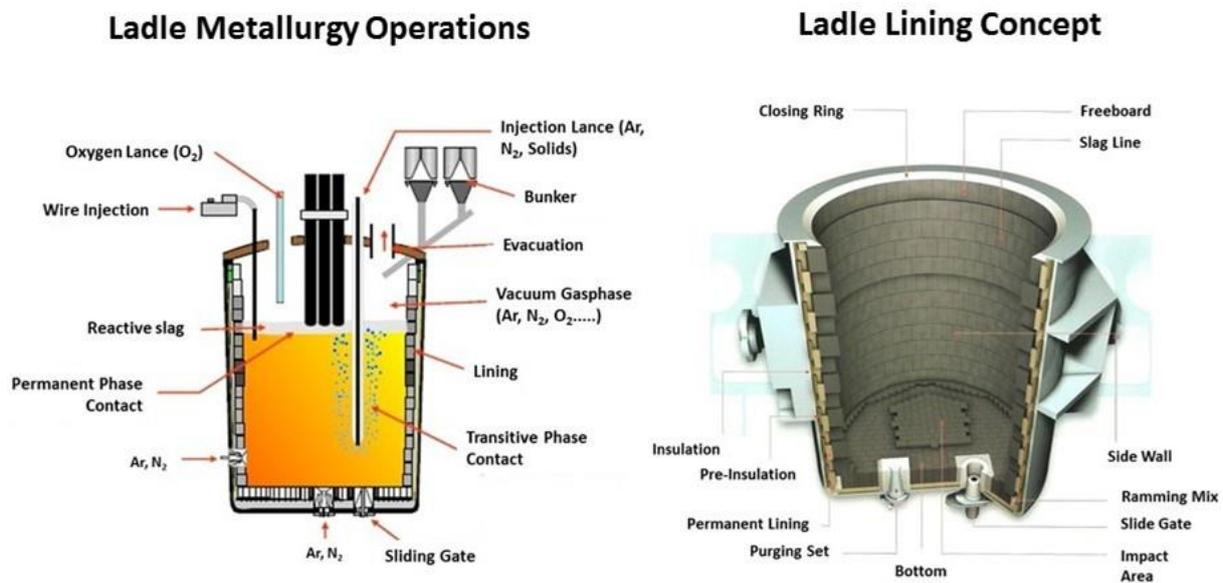


Figure 6: Ladle Metallurgy Operations & Lining Concept

The typical product split is 86,6 % bricks (in 5 qualities and 8 formats), 6,3% of ladle backfiller, 5,8% of castables and 1,3% of mortar. Of course these figures can vary due to the detailed lining concept.

The difference in value in use between different refractory qualities can be defined as follows:

- a) High quality refractory in general should achieves better performance results.
- b) Uniform material quality in individual ladles can only be guaranteed from a single source (no patching).
- c) The optimum design of a zoned and balanced lining guarantees a minimum of material qualities and shapes. This minimizes the requirements for cutting losses during installation (normally 4%, reduced 1-2%).
- d) The standard deviation in steel ladle refractory lining weight is 2% of the installed material which is a direct cost saving arising from higher quality material.
- e) Converted to steel this option for lean lining construction can be converted to steel by the factor of the specifics weights of refractory and steel, which is approximately 2,8. This results in another cost saving of 5,6%.
- f) In combination with high efficient maintenance techniques (gunning, slag conditioning) even better results in the range of 10% will be obtained.

The total direct related potential of the high value refractory material can be accelerated to 15-20% compared to standard supplies. In this estimate other benefits resulting from safety, availability and reliability advantages and process speed and “accuracy” of metallurgical results are not even taken into account. **Figure 7** shows the performance requirements on refractory material in an overview.

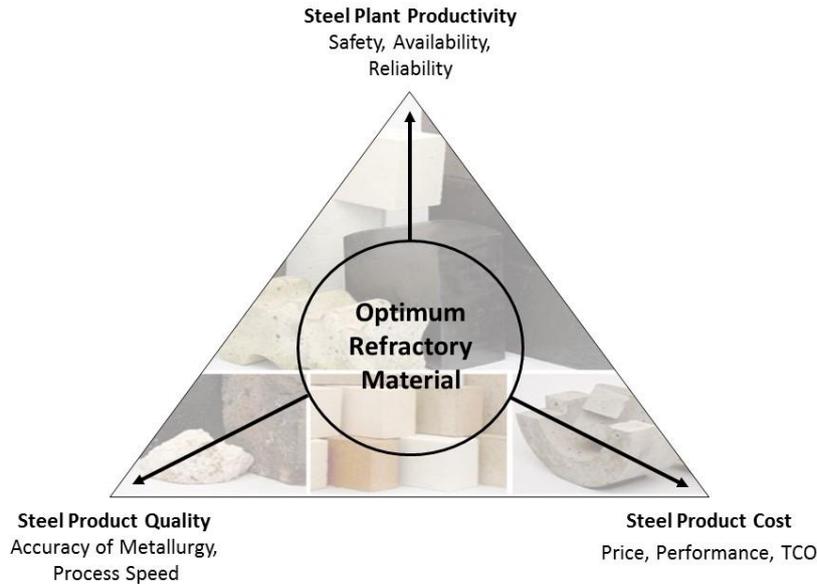


Figure 7: Performance Requirements for Refractory Products [10]

5. Steel Quality Relevance of Refractory Products

A key for success in the metallurgical results as well as in the refractory performance results is the base knowledge in metallurgical slag conditioning [11]. **Figure 8** shows the four phase slag component diagrams $(CaO) - (Al_2O_3) - (SiO_2) - (MgO)$, representing normally > 96% of ladle refining slags. The diagram shown represents a horizontal cut through a pyramid with (MgO) being the vertical vector in z-direction. The cut shown is at a (MgO) content of 10%.

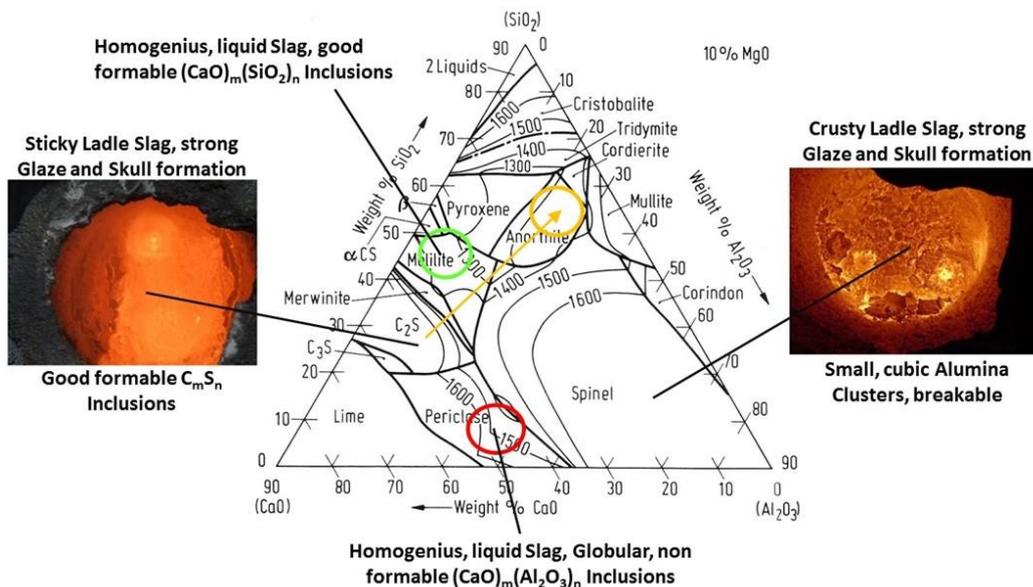


Figure 8: Metallurgical Slag Composition Control and Refractory Performance [11]

Homogenous liquid, reactive, metallurgical slag compositions are located in the red and green (yellow) tagged area of the diagram, whereas the heterogeneous slags, which generates glaze and skull are located towards the corners of the diagram. The red area is typical for Aluminium killed steel. They represent an inclusion type which is liquid until steel solidification, similar to Calcium treated steel. Therefore no clogging will appear. These slags have a very high De-Sulphurization capacity. The green area is typical for Silicon killed steel. In this case Silica addition by sand or gravel can be used to increase the Silica content and to liquefy the slag. These slags have low basicity and almost no De-Sulphurization capacity. The yellow area can be reached by

adding crushed chamotte ($\text{Al}_2\text{O}_3 - \text{SiO}_2$) refractory to the slag which will then change the composition to the liquid area of the diagram tagged.

In general all these reactive slags in fact are refractory “eaters”, e.g. they are aggressive and are causing chemical refractory corrosion. But the solubility of these slag for MgO is limited to saturation. The saturation curves have been described in many publications. So by knowledge of the steel type, the desired de-oxidation practice (Al- or Si-killed) and the required De-S practice and in consequence the required slag composition are known. The slag can be saturated by MgO additions of burned Magnesite or burned Dolomite and the refractory wear can be controlled by this practice. This technology is not new but state-of-the-art as reported in many metallurgical reports and papers. One Example is shown in **Figure 9** below [11].

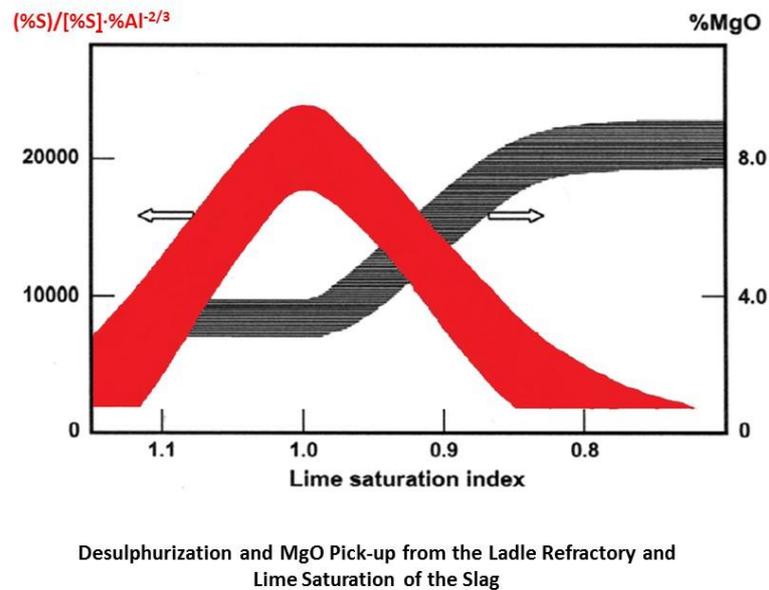


Figure 9: Metallurgical Slag Composition, De-S Efficiency and Refractory Performance Control [12]

Another proof of the interaction between steel type and refractory result is given in **Figure 10** showing the long-term performance of MgO-C wear linings in different steelmaking applications and environment. Each dot in the diagram represents a ladle lining campaign. The red dots (brown average curve) represent the results of Al-killed steel for slab fabrication with high Alumina slag. The green dots (green average curve) represent the results for Si-killed steel with high Silica slags. In both cases slag conditioning with MgO is not applied.

The results achieved in the A-killed route are in general higher than in the Si-killed route but in both routes the results are very unstable. The average in both applications shows production performance trends, whereas the scattered dots are clearly demonstrating that during steelmaking a lot of parameters must be controlled to avoid abnormal handling of the refractory which will lead to sudden failure and only poor results. These factors are:

- Correct storage and handling of the refractory material
- Correct workmanship of lining installation
- Maintenance of ladle shells (repair of deformations and lip rings)
- Control of even ladle shell temperature distribution by isolation
- Correct lining dry out and preheating before 1st hot use
- Consequent preheating during the hot cycle to reduce thermocycling stress
- Avoidance of excessive heat load by arcing in the LF
- Avoidance of mechanical stress during ladle movements
- Avoidance or removal of slag glaze and skull
- Avoidance or removal of steel skull frozen in the ladles etc.

All these factors require continuous, controlled steelmaking operations, skilled workmanship, sufficient availability of resources (men, time, budget) and experienced plant management to succeed.

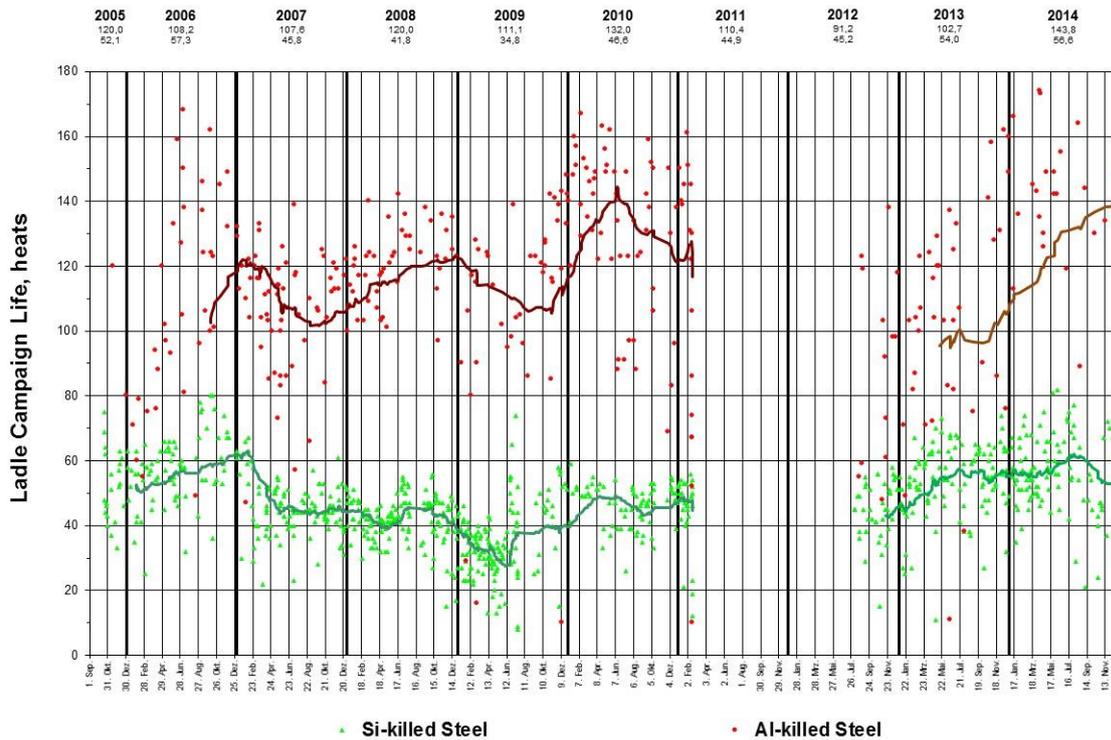


Figure 10: Ladle Refractory Performance with different Steel Types and Process Conditions

A complete different task for the refractory material is the functionality of the flow control elements used in continuous casting. In this process basically:

- prevention of slag carry over from ladle to tundish and tundish to mould
- prevention of tundish slag and mold slag emulsification and
- prevention of air ingress into the system

are the main challenges, as shown in **Figure 11**. The critical areas are marked in red colour for the slag carry over and emulsification areas and in blue colour for the shrouding areas. The choice of the best suitable system including a qualified Argon sealing system to compensate vacuum effects appearing inside of the tubes in case they are not completely filled with liquid steel during casting. CFD simulation support to evaluate the best fitting design is recommended

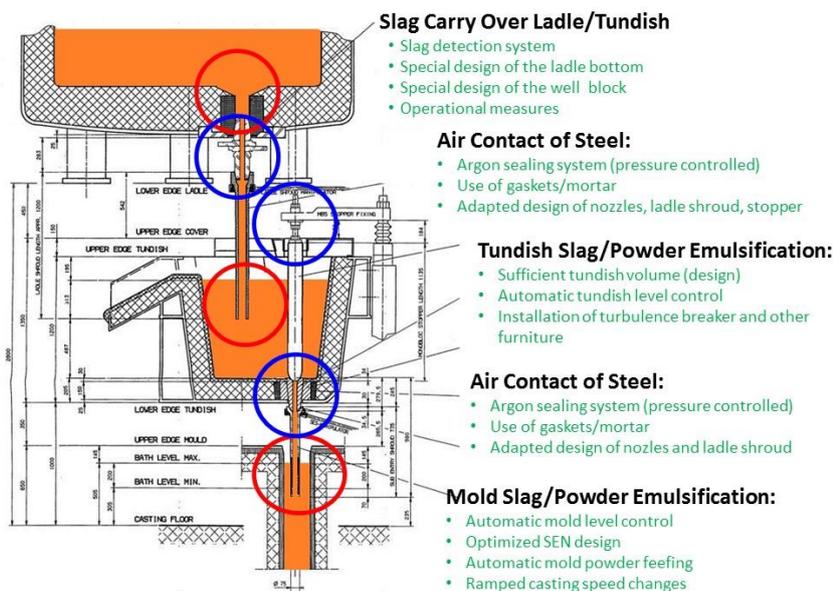


Figure 11: Flow Control Elements and Tasks

6. Cost Efficiency of Refractory Products (TCO Approach)

A frequently used methodology to evaluate the real benefits of purchased goods and services is the so called TCO (Total Cost of Ownership) approach. The idea is similar to the “iceberg” theory which says that in the deep water only the tip of the iceberg will show up over the water surface, the big chunk of the iceberg will swim below the surface. Adapted to procurement activities the model is defined as shown in **Figure 12**. Above the water surface the purchase price of the product or service is the dominating factor. Below the surface other elements summarized under “internal business cost” and cost of “value in use” must be taken into account.

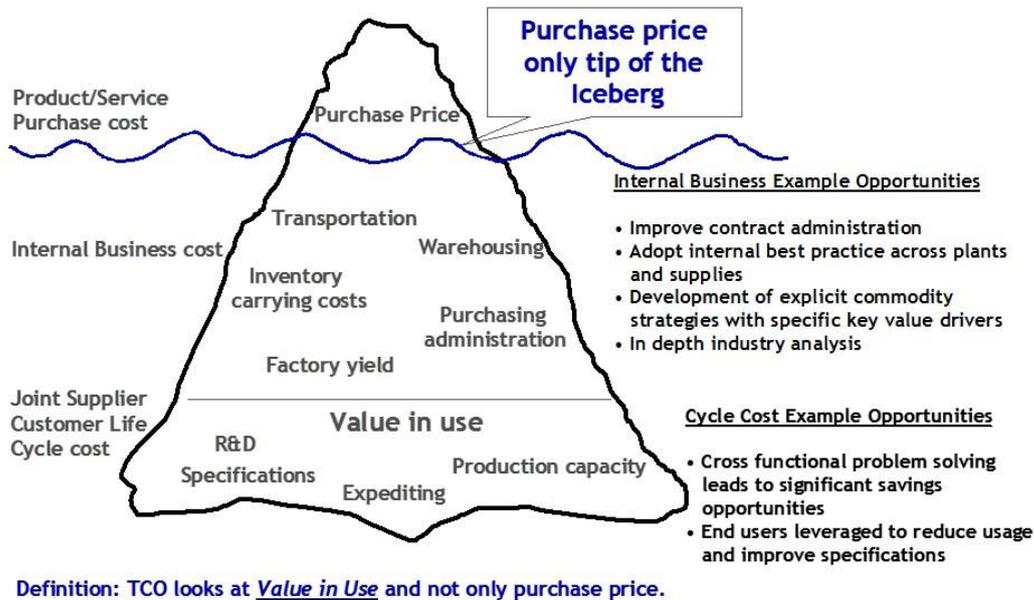


Figure 12: The TCO (Total Cost of Ownership) Concept [13]

Also for the refractory purchase in steelmaking applications this model can be applied. With respect to logistics and operations in a steel plant, the model to calculate the TCO was modified and adapted to be suitable for steel plant operations. It is of practical use to include the purchase price into the so called “life cycle” cost and to summarize all value in use parameters inside the so called “operational” cost. It should be mentioned, that the TCO model applied does not indicate for any direct savings. It just defines a cost volume which is influenced by the refractory but it clearly shows the impact of the refractory material performance on the total operation cost.

In the steel plant example shown, the result came that 28% of the TCO is the “life cycle” cost, basically the refractory material and the installation service. The remaining 72% of the TCO is the operational cost.

Fluxing agents are all slag forming fluxes used during melting, ladle metallurgy refining and casting. Relining and REF maintenance losses are the theoretical cost for unavailability of metallurgical vessels during relining or REF maintenance activities. Cost for yield losses are basically the Fe-losses with the furnace slag. Their value loss is very high, because Fe-units solute in the slag cannot be recovered from the slag and are a total downgrade from steel to slag value. This point is very important to be recognized since it clearly shows the importance to control as well the total slag volume of the metallurgical processes and the iron losses by oxidation. It’s an indicator for metallurgical efficiency.

The total TCO-cost level in this example with 72 USD/t Steel seems high, but already the life cycle cost with 20,28 USD/t Steel are very high. The final split between life cycle and operation cost (30/70), between purchase price and life cycle cost (80/20) and between slag management and vessel availability (70/30) has been confirmed in many examples from integrated mills as well as from electrical steel mills. So by knowing the total refractory spend of an individual plant everyone can estimate about the refractory TCO of the plant.

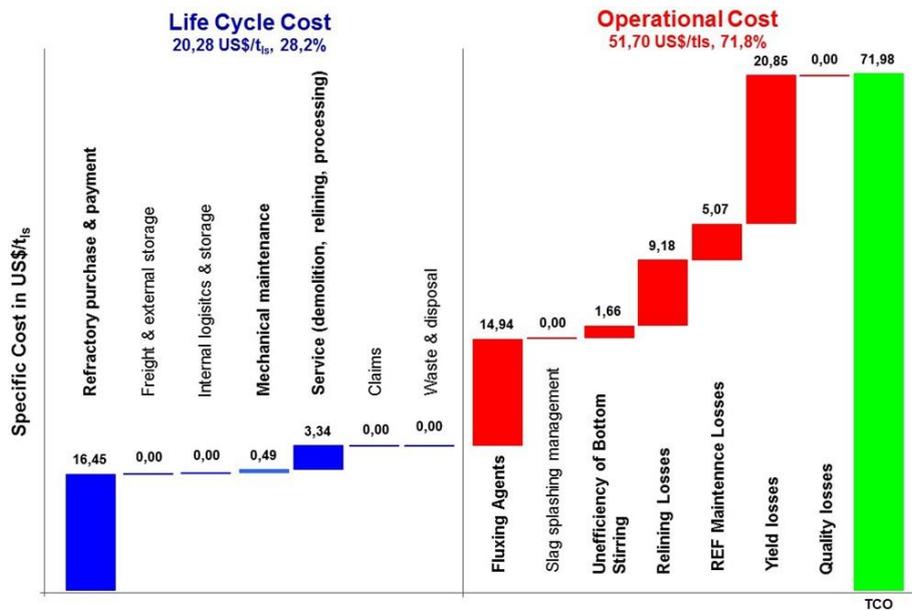


Figure 13: TCO Example from an integrated Mill

7. Future Trends & Conclusion

Future trends for the refractory industry can be derived from the facts and figures above but were also discussed during the UNITECR conference 2015 in Vienna. Here several speakers were talking about the cleanliness trends in steel production (600 ppm of impurities down to 100 ppm of impurities) which need more aggressive metallurgical slags and because of this higher wear resistant refractory materials with higher Carbon content. Also for some steel grades (basically exposed automotive sheets only) the Carbon pick-up from refractory is a concern, this will not change the general trends.

In consequence this trend will increase the replacement of Alumina based Andalusite and Bauxite grades by Magnesite-Carbon (fired & fused), Alumina-Magnesite-Carbon and Dolomite grades. A clear market demand of the steel industry was forecasted in the use of thinner steel vessel linings to increase the value in use by higher steel tap-weight and lower specific refractory installation in operations. The benefits of high quality material in this respect were discussed earlier in this paper.

The long term total refractory consumption for steelmaking is seen more in the corridor of 5-10 kg/t in average, following the Japanese trend, than higher. Refractory producers worldwide have to consolidate their growth expectations to these market condition forecast to develop their mid- and long term strategies accordingly. This is more important since global growth of steel production (driven by China for the last two decades) has come to stagnation and will not recover in foreseeable period of time.

In general it can be concluded that the future for refractory materials and minerals demand is of course assured in long term. Without refractory steelmaking will never be possible. But type of mineral does matter. But a closer cooperation and new business models to be introduced between refractory and refractory mineral suppliers and steel customers is required to survive in the upcoming consolidation phase of the steel manufacturing industry in the next two decades.

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